



US009199662B2

(12) **United States Patent**  
**Ueno et al.**

(10) **Patent No.:** **US 9,199,662 B2**  
(45) **Date of Patent:** **Dec. 1, 2015**

(54) **RACK AND PINION STEERING GEAR UNIT**

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(75) Inventors: **Seiji Ueno**, Gunma (JP); **Toshiyuki Arai**, Gunma (JP); **Ryota Sugihara**, Gunma (JP)

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(73) Assignee: **NSK LTD**, Tokyo (JP)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **13/574,459**

(22) PCT Filed: **Apr. 24, 2012**

(86) PCT No.: **PCT/JP2012/060934**

§ 371 (c)(1),  
(2), (4) Date: **Oct. 9, 2012**

(87) PCT Pub. No.: **WO2012/147724**

PCT Pub. Date: **Nov. 1, 2012**

(65) **Prior Publication Data**

US 2013/0074621 A1 Mar. 28, 2013

(30) **Foreign Application Priority Data**

Apr. 25, 2011 (JP) ..... 2011-096717  
May 20, 2011 (JP) ..... 2011-113242

(51) **Int. Cl.**  
**F16H 19/08** (2006.01)  
**B62D 3/12** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **B62D 3/12** (2013.01); **Y10T 74/18096** (2015.01)

(58) **Field of Classification Search**  
CPC ..... B62D 5/22; B62D 3/12; B62D 17/00; F16H 19/04  
USPC ..... 74/30, 10.39, 29, 388 PS; 180/426, 425  
See application file for complete search history.

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*Primary Examiner* — William Kelleher

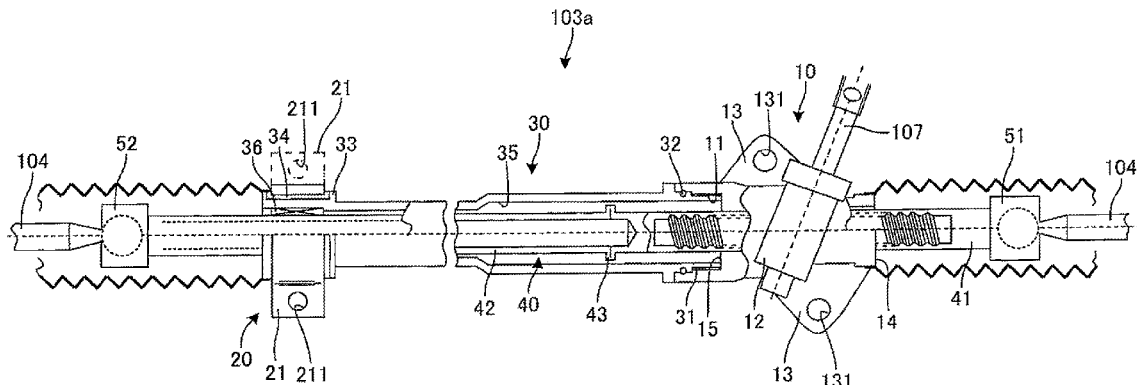
*Assistant Examiner* — Zakaria Elahmadi

(74) *Attorney, Agent, or Firm* — Katten Muchin Rosenman LLP

(57) **ABSTRACT**

A lightweight and low cost gear housing for a steering gear unit is achieved. Together with forming an outward-facing flange shaped convex engagement section 43 around the middle section in the axial direction of a rack shaft 40, a gear housing is constructed that comprises a pinion-side housing 10, a non-pinion-side housing 20, and an intermediate cylindrical section 30. As a result, movement of the rack shaft 40 toward the pinion side and the non-pinion side is restricted by both ends of the pinion-side housing 10. Therefore, portions that require large strength can be limited to the pinion-side housing 10 that is short in the width direction of the vehicle, so by reducing the wall thickness of the intermediate cylindrical section 30, or by making the intermediate cylindrical section 30 using a flexible material, it is possible to make the member lightweight, as well as processing become easier, so it becomes possible to reduce the manufacturing cost.

**8 Claims, 12 Drawing Sheets**



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Fig.1

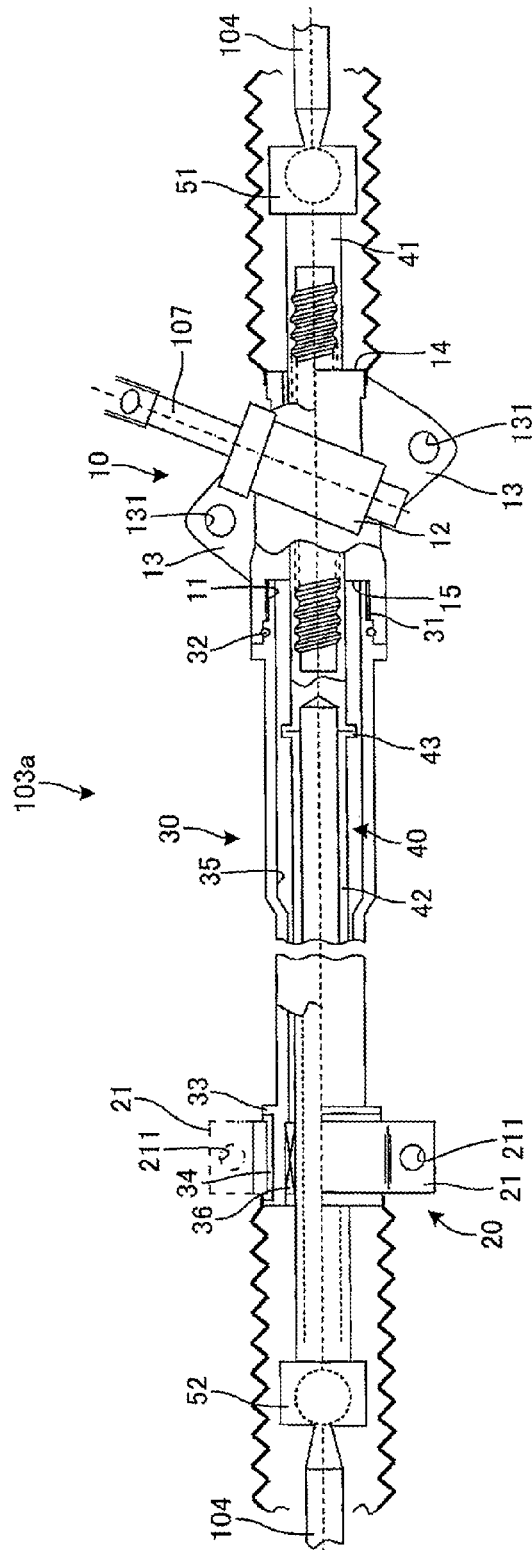


Fig.2

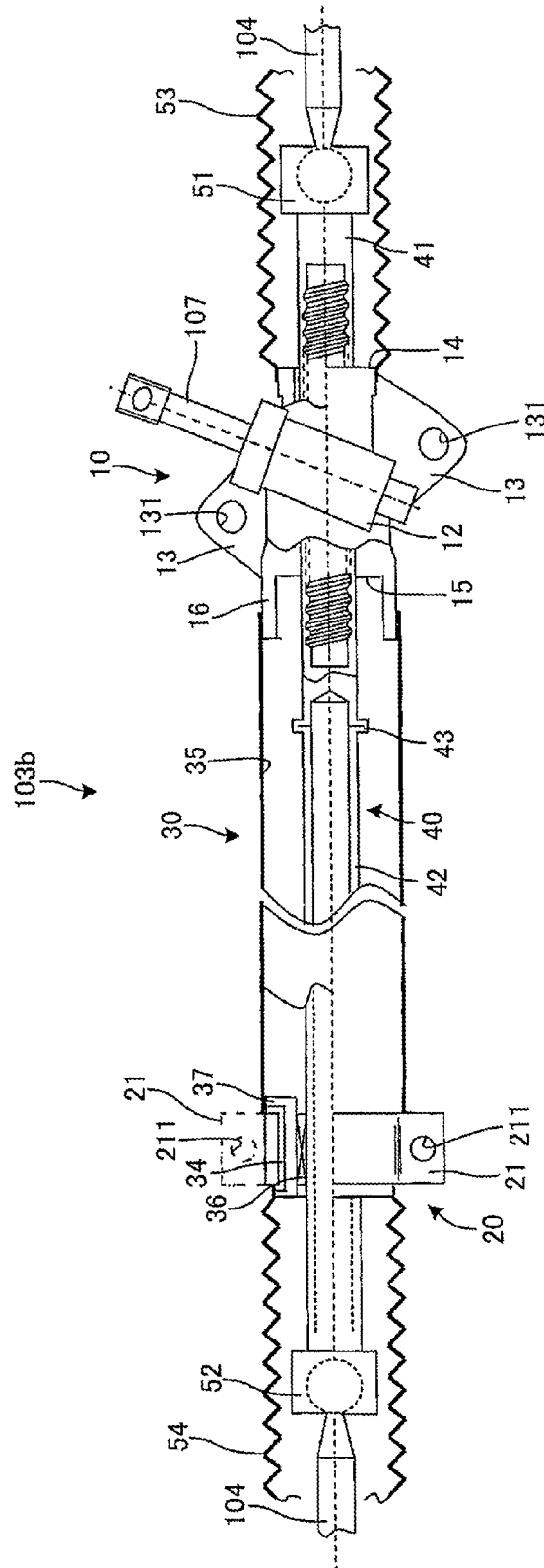


Fig.3

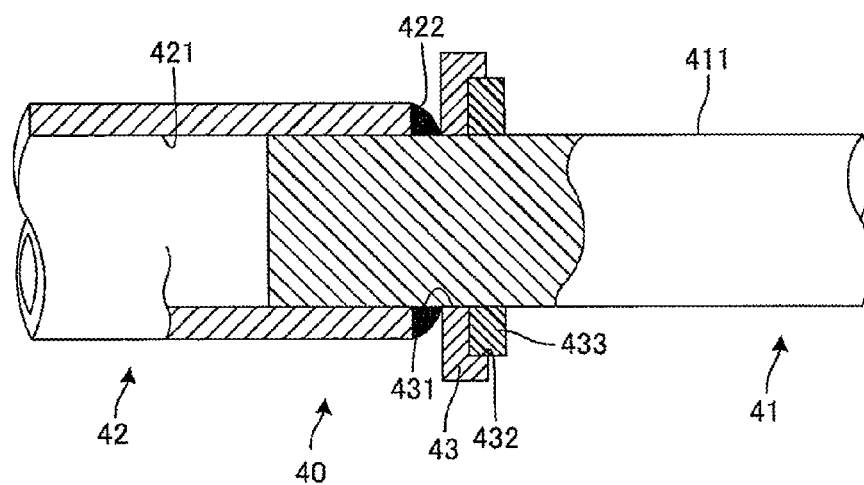


Fig.4

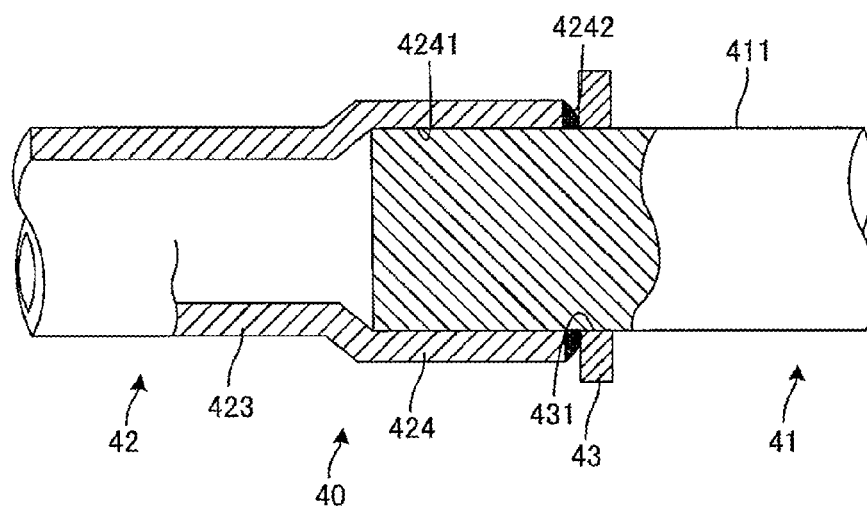


Fig.5

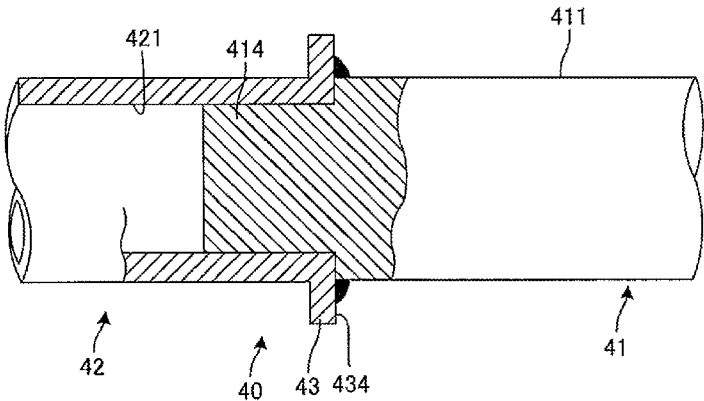


Fig.6

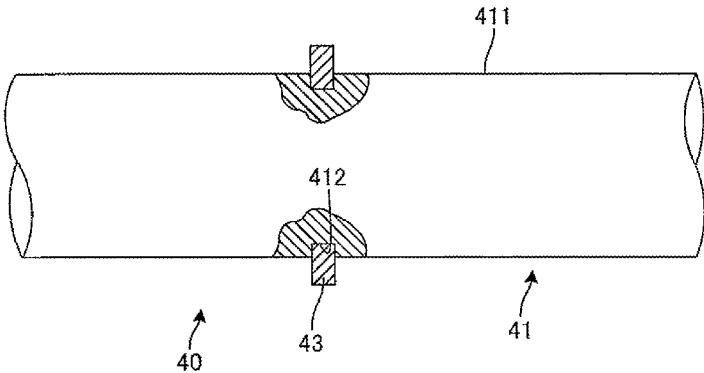


Fig.7

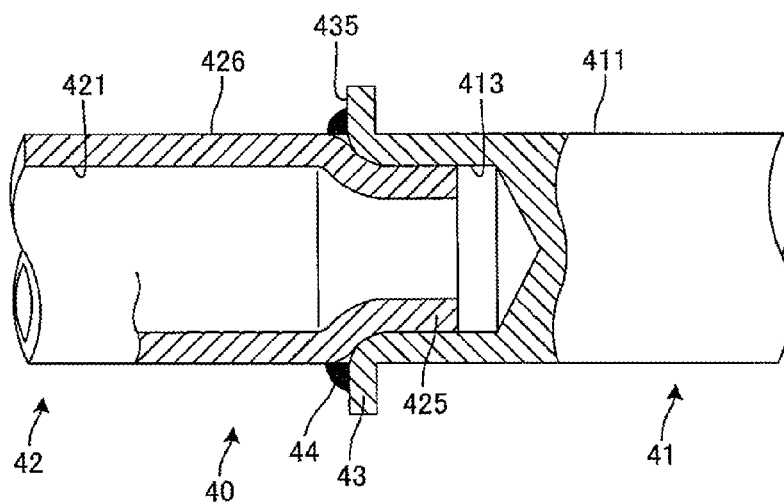


Fig.8

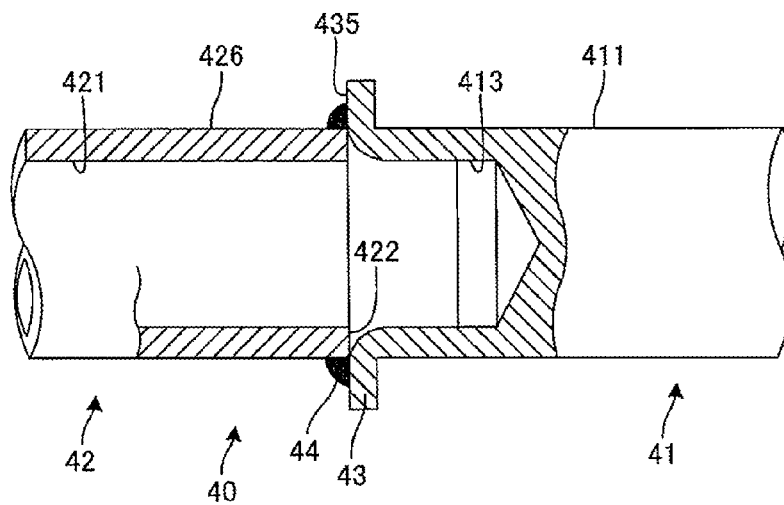


Fig.9

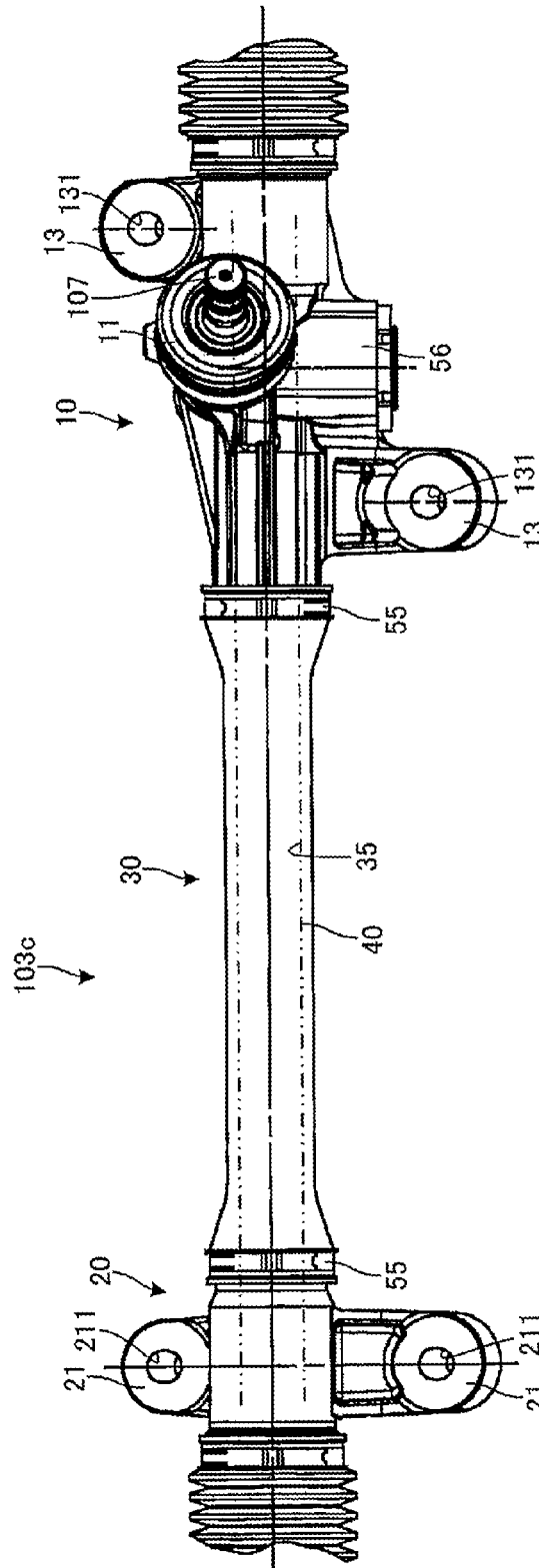




Fig.10

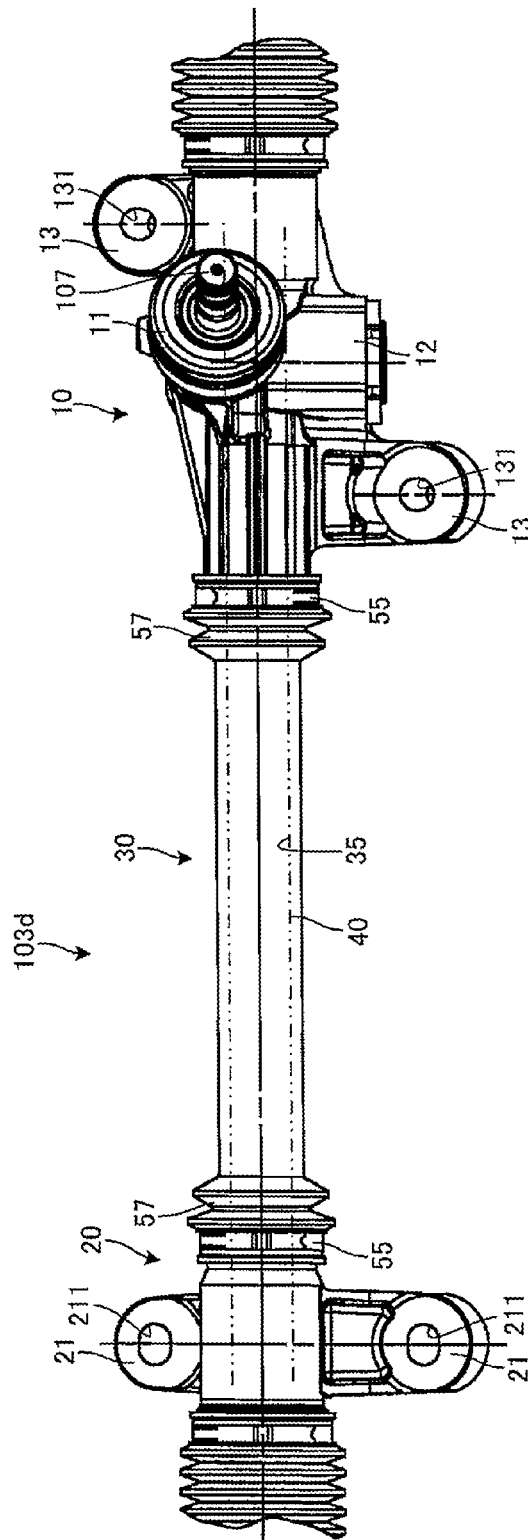


Fig.11

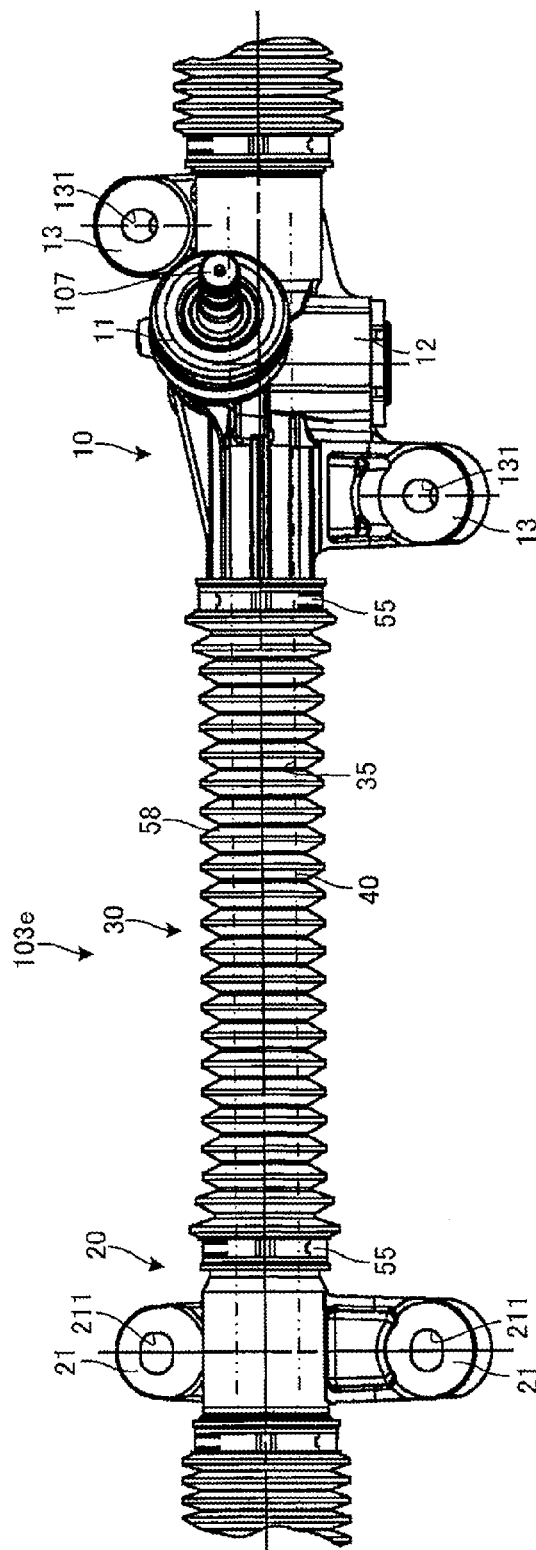


Fig.12

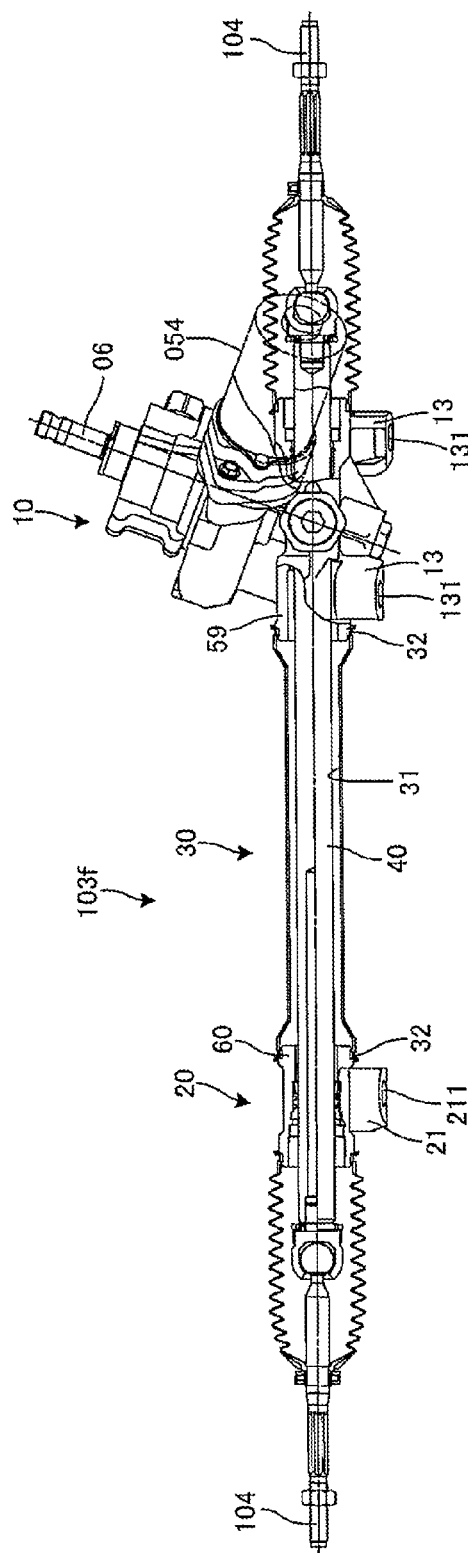


Fig.13

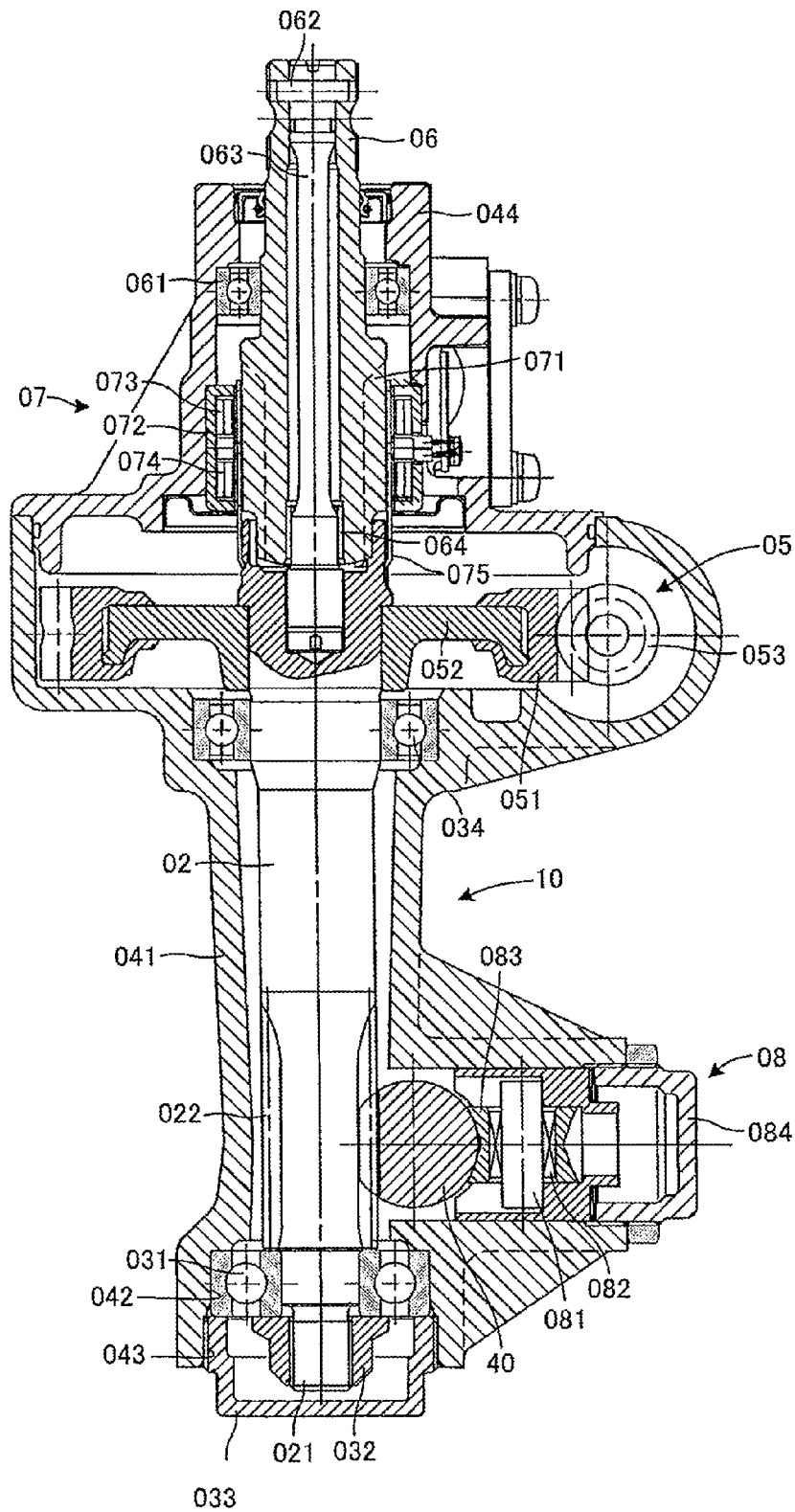


Fig.14

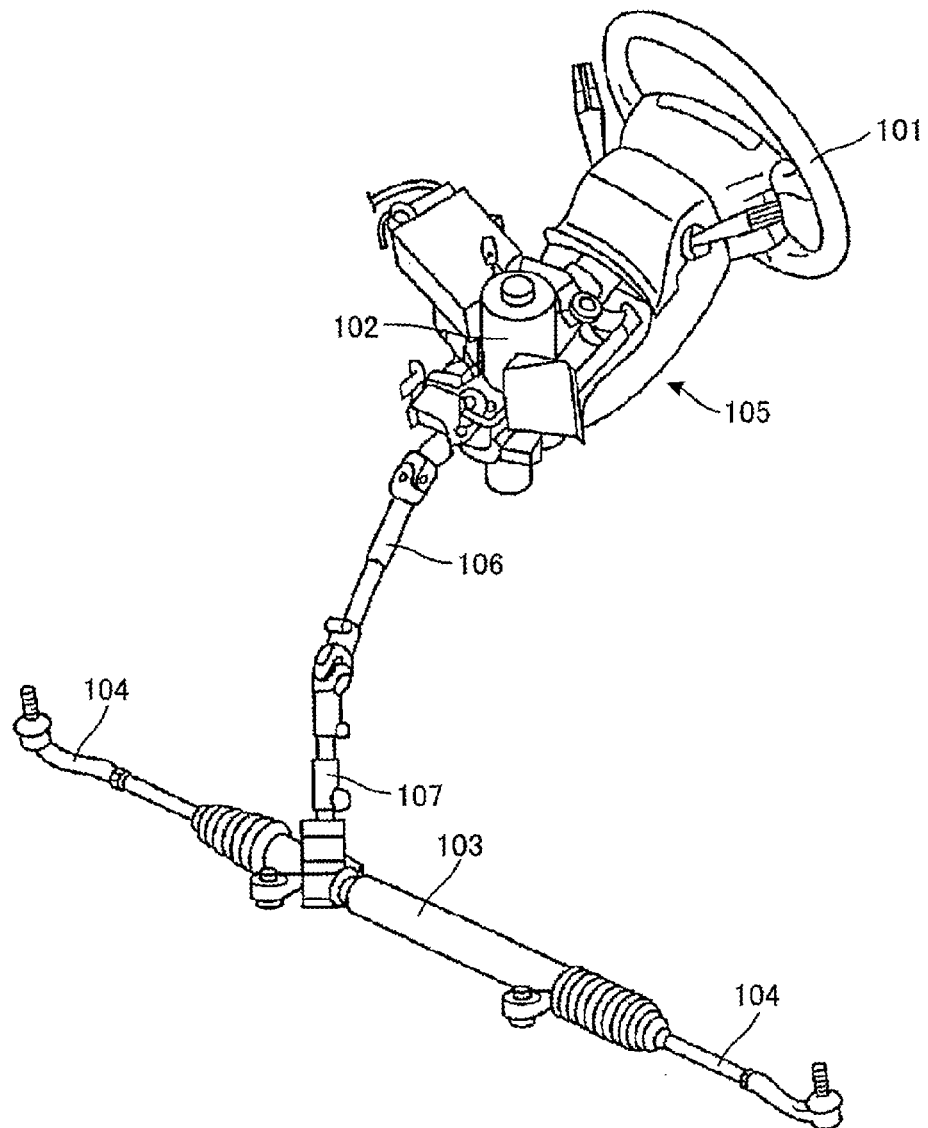
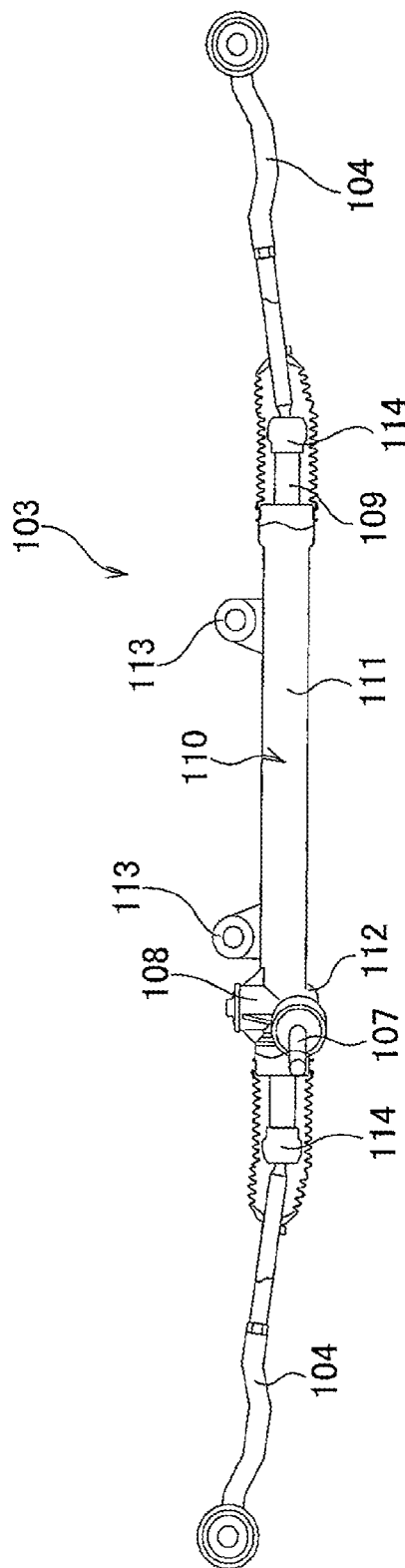


Fig.15



## RACK AND PINION STEERING GEAR UNIT

## TECHNICAL FIELD

The present invention relates to a rack and pinion steering gear unit of a steering apparatus for applying a steering angle to steered wheels of an automobile.

## BACKGROUND ART

A rack and pinion steering gear unit is used as a mechanism for converting rotating motion that is input from a steering wheel to linear motion for applying a steering angle. Steering apparatuses that comprise a rack and pinion steering gear unit are well known, and have been disclosed for example in JP61-129670(U), JP2005-96591(A) and JP2009-56827(A). FIG. 14 illustrates construction of an example of a steering apparatus in which a rack and pinion steering gear unit is assembled. In this steering apparatus, in order to reduce the operating force for operating the steering wheel 101, auxiliary steering force from a motor 102 that is installed in the middle of the steering column 195 is applied to the steering shaft. The movement of the steering shaft that rotates as the steering wheel 101 is operated is transmitted to an intermediate shaft 106, which causes a rack shaft of a rack and pinion steering gear unit 103 to reciprocate by way of a pinion shaft 107, and this steers the steered wheels by way of tie rods 104.

As illustrated in FIG. 15, the steering gear unit 103 comprises a rack shaft 109 and a gear housing 110 that houses the rack shaft 109 so as to be able to displace in the axial direction therein. The gear housing 110 is integrally formed by performing die casting of a metal such as an aluminum alloy. By making the gear housing 110 using metal in this way, it is possible to receive the steering reaction force that is transmitted from the wheels when steering. The gear housing 110 has a cylindrical shaped main housing section 111 that is open on both ends in the lengthwise direction, and a sub housing section 112 that is provided on the outer circumferential surface of the portion near one end in the lengthwise direction of the main housing section 111, and has a center axis that is in twisted position relationship with the center axis of the main housing section 111. The internal spaces of the main housing section 111 and the sub housing section 112 are connected with each other. The gearing housing 110 is supported by and fastened to the vehicle body (frame) by bolts or studs that are inserted through a pair of installation flanges 113 that are provided at two locations around the outer circumferential surface of the main housing section 111 that are separated in the axial direction.

The rack shaft 109 comprises rack teeth that are formed on the part of the side surface in the axial direction. Except for the portion where the rack teeth are formed, the rack shaft 109 is a circular rod shape with the outer circumferential surface thereof being a cylindrical surface. With pinion teeth that are formed on the tip end section of the pinion shaft 107 engaged with the rack teeth of the rack shaft 109, the pinion shaft 107 is supported by the sub housing section 112 so as to be able to rotate. A cylinder section 108 that is equipped with a pressing block is provided on the portion in the radial direction of the main housing section 111 on the opposite side from the sub housing section 112.

In this kind of rack and pinion steering gear unit, construction is such that when the operator operates the steering wheel 101, the rack shaft 109 moves in the axial direction, and when reaching the stroke end, ball joint sockets 114 that are fastened to both ends of the rack shaft 109 in the width direction of the vehicle come in contact with the both ends of the main

housing section 111 of the gear housing 110 in the width direction of the vehicle, and as a result, movement of the rack shaft 109 is stopped, and the movement distance of the rack shaft 109 is limited.

In the case of this kind of construction, the length of the gear housing 110 in the width direction of the vehicle becomes long due to the wide space in the width direction of the vehicle between the ball joint sockets 114 that are fastened on both ends of the rack shaft 109. Therefore, the thrust load when the ball joint sockets 114 come in contact with the both ends of the main housing section 111 of the gear housing 110 is supported by these both ends of the gear housing 110 that is long in the width direction of the vehicle, so it is necessary that the gear housing 110 have large strength. In order for that, the gear housing 110 must be formed using metal material having large rigidity, and the thickness of the gear housing 110 must be thick. As a result, there are problems in that the weight of the gear housing 110 increases and the manufacturing cost increases.

Furthermore, because the rack shaft 109 is long in the axial direction, there is a problem in that when integrally forming the gear housing 110 by casting, the material cost and processing cost increases.

JP61-129670(A), JP2009-56827 and JP2005-96591 disclose construction wherein the steering gear housing is divided into two or more members. Moreover, JP2005-96591 (A) discloses construction wherein the gear housing is divided into three parts, left and right mounting sections that are mounted to the vehicle body, and a middle section; and of these, the left and right mounting sections are formed of an aluminum material, and the middle section is made of a steel material. With this kind of construction, the length in the axial direction of the left and right mounting sections is shorter than the length in the axial direction of the integrated gear housing, so casting work becomes easier, as well as other processing also becomes easier. However, even in the case of construction wherein the gear housing is divided, thrust load when the ball joint sockets come in contact with the gear housing is supported by both ends of the gear housing in the axial direction of the vehicle, so the gear housing still must have large strength. In order for this, it is necessary that the thickness of the gear housing be thick, and gear housing must be made of a metal material having large strength. As a result, it is not possible to solve the problem of increased weight and increased manufacturing cost of the gear housing.

## RELATED LITERATURE

## Patent Literature

[Patent Literature 1] JP61-129670(A)  
[Patent Literature 2] JP2009-56827(A)  
[Patent Literature 3] JP2005-96591(A)

## SUMMARY OF THE INVENTION

## Problem to be Solved by the Invention

In consideration of the problems above, the object of the present invention is to reduce the weight and manufacturing cost of the gear housing of a rack and pinion steering gear unit.

## Means for Solving the Problems

The rack and pinion steering gear unit of the present invention comprises:

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a rack shaft that reciprocates according to rotation of a pinion shaft;  
 ball joint sockets that are formed on both ends of the rack shaft and have a larger diameter than the rack shaft;  
 a pinion-side housing made of metal that supports a pinion-side end section of the rack shaft where the pinion shaft is located so that sliding movement of the rack shaft is possible, and that can be fastened to the vehicle frame; and  
 a convex engagement section that is formed in the middle section in the axial direction of the rack shaft between the pinion-side end section and the non-pinion-side end section that is on the opposite side from the pinion-side end section, and that has a larger diameter than the rack shaft.

In the rack and pinion steering gear unit of the present invention, as the rack shaft displaces, one of the ball joint sockets that is attached to the pinion-side end section comes in contact with one end of the pinion-side housing, and restricts movement of the rack shaft toward the non-pinion side, and the convex engagement section comes in contact with the other end of the pinion-side housing, and restricts movement of the rack shaft toward the pinion side.

Preferably, the rack and pinion steering gear unit further comprises a non-pinion-side housing made of metal that supports the non-pinion-side end section of the rack shaft so that sliding movement of the rack shaft is possible, and that can be fastened to the vehicle frame, and a hollow cylindrical shaped intermediate cylindrical section that is connected to the pinion-side housing on one end, and is connected to the non-pinion-side housing on the other end, and covers the middle section of the rack shaft.

In this case, preferably, the non-pinion-side housing supports the non-pinion-side end section of the rack shaft by way of an elastic member such as rubber so that sliding movement of the rack shaft is possible.

Preferably, the rack shaft is formed by connecting a solid shaft on which a rack is formed and a hollow shaft on which the rack is not formed, and the convex engagement section is formed around the connecting section between the solid shaft and the hollow shaft.

Preferably, a damper made of an elastic material such as rubber is attached to the contact surface of the convex engagement section that comes in contact with the other end of the pinion-side housing.

Preferably, the intermediate cylindrical section can expand and contract in the axial direction of the rack shaft. More specifically, the intermediate cylindrical section is formed using a material having flexibility, and the entire length or part of the intermediate cylindrical section has a bellows shape. As an example of material having flexibility is synthetic resin or rubber.

#### Effect of the Invention

With the rack pinion steering gear unit of the present invention constructed as described above, together with being able to restrict movement of the rack shaft toward the non-pinion side by one end of the pinion-side housing coming in contact with a ball socket joint that is formed on the end section on the pinion side of the rack shaft, it is possible to restrict movement of the rack shaft toward the pinion side by the other end of the pinion-side housing coming in contact with the an convex engagement section that is formed in the middle section in the axial direction between the end section on the pinion side of the rack shaft and the end section on the non-pinion side. Therefore, in the case of the present invention, it

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is possible to use both ends of the pinion-side housing that is short in the width direction of the vehicle, so as to support thrust loads that act when restricting the movement of the rack shaft in the left-right direction, so the portion that requires large strength can be limited to the pinion-side housing that has a short length in the width direction of the vehicle. Consequently, together with being able to reduce the weight of the entire housing of the steering gear unit, it is possible to reduce manufacturing costs by simplifying the casting and other processes.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear of a steering gear unit of a first example of an embodiment of the present invention.

FIG. 2 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear of a steering gear unit of a second example of an embodiment of the present invention.

FIG. 3 is a front view with a partial cross-sectional view illustrating a variation of a convex engagement section that is formed on the rack shaft.

FIG. 4 is a front view with a partial cross-sectional view illustrating a variation of a convex engagement section that is formed on the rack shaft.

FIG. 5 is a front view with a partial cross-sectional view illustrating a variation of a convex engagement section that is formed on the rack shaft.

FIG. 6 is a front view with a partial cross-sectional view illustrating a variation of a convex engagement section that is formed on the rack shaft.

FIG. 7 is a front view with a partial cross-sectional view illustrating a variation of a convex engagement section that is formed on the rack shaft.

FIG. 8 is a front view with a partial cross-sectional view illustrating a variation of a convex engagement section that is formed on the rack shaft.

FIG. 9 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear of a steering gear unit of a third example of an embodiment of the present invention.

FIG. 10 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear of a steering gear unit of a fourth example of an embodiment of the present invention.

FIG. 11 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear of a steering gear unit of a fifth example of an embodiment of the present invention.

FIG. 12 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear of a steering gear unit of a sixth example of an embodiment of the present invention.

FIG. 13 is a vertical cross-sectional view illustrating the engagement section between the pinion shaft and the rack in FIG. 12.

FIG. 14 is a perspective view illustrating the overall steering apparatus to which the steering gear unit of the present invention is applied.

FIG. 15 is a top view illustrating a conventional steering gear unit.

#### MODES FOR CARRYING OUT THE INVENTION

##### Example 1

FIG. 1 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear unit 103a of this



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example. The steering gear unit **103a** of this example is installed to the vehicle body frame (not illustrated in the figure) such as the front sub frame. The front side that is orthogonal to the paper surface in FIG. **1** is the upward side of the vehicle body, the back side that is orthogonal to the paper surface in FIG. **1** is the downward side of the vehicle body, the left-right direction in FIG. **1** is the width direction of the vehicle, the upward direction in FIG. **1** is the direction toward the rear of the vehicle body, and the downward direction in FIG. **1** is the direction toward the front of the vehicle body.

The steering gear unit **103a** of this example comprises a pinion-side housing **10** on the right side of FIG. **1**, a non-pinion-side housing **20** on the left side of FIG. **1**, and an intermediate cylindrical section **30** that connects the pinion-side housing **10** and the non-pinion-side housing **20**.

Of these members, the pinion-side housing **10** and the non-pinion-side housing **20** are formed by casting a metal such as an aluminum alloy.

On the other hand, the hollow, cylindrical shaped intermediate cylindrical section **30** is formed by injection molding or blow molding of synthetic resin. Male threads **31** are formed around the outer circumferential surface of the right end of the intermediate cylindrical section **30**. The right end of the intermediate cylindrical section **30** is fastened to the pinion-side housing **10** by screwing the male threads **31** into female threads **11** that are formed around the inner circumferential surface of the left end of the pinion-side housing **10**. An O-ring **32** is located between the inner circumferential surface of the left end of the pinion-side housing **10** and the outer circumferential surface of the right end of the intermediate cylindrical section **30**, and this O-ring **32** maintains an airtight seal in the connecting section between the pinion-side housing **10** and the intermediate cylindrical section **30**. On the other hand, a flange section **33** is formed around the outer circumferential surface of the left end of the intermediate cylindrical section **30**. This flange section **33** is fastened to the inner circumferential surface of the non-pinion-side housing **20** by way of a damper made of an elastic material.

A rack shaft **40** is located on the inside of the inner circumferential surface **35** of the intermediate cylindrical section **30** so as to be capable of sliding movement in the left-right direction of FIG. **1**. A bearing bushing **36** is fastened on the inside of the left end of the inner circumferential surface **35** of the intermediate cylindrical section **30**, and supports the left end of the rack shaft **40** so as to be capable of sliding movement thereof.

Ball joint sockets **51**, **52** are formed on both ends in the axial direction of the rack shaft **40**. Tie rods **104** are connected to these ball joint sockets **51**, **52**, and these tie rods **104** are connected to the wheels by way of a knuckle arm (not illustrated in the figure). The ball joint sockets **51**, **52** are formed with a diameter that is greater than that of the rack shaft **40**.

A column shaped boss **12** for inserting the pinion is integrally formed in the pinion-side housing **10**. A pinion (not illustrated in the figure) that engages with the rack shaft **40** is formed around the outer circumferential surface of the bottom end of the pinion shaft **107** that is inserted through this column shaped boss **12**. On the other hand, as illustrated in FIG. **14**, the top end of the pinion **107** is connected to the bottom end of an intermediate shaft **106** that is connected to the steering wheel **101**.

As the operator rotates the steering wheel **101**, the rotation is transmitted by the intermediate shaft **106** and a universal joint, and causes the pinion of the pinion shaft **107** to rotate. Due to the rotation of this pinion, the rack shaft **40** slides in the left-right direction, which changes the steering angle of the wheels.

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A pair of vehicle-installation boss sections **13**, **21** is respectively formed in both the pinion-side housing **10** and non-pinion-side housing **20**. One circular installation hole **131**, **211** is formed in the up-down direction of the vehicle in each of the vehicle-installation boss sections **13**, **21**, respectively.

Bolts (not illustrated in the figure) are inserted into these installation holes **131**, **211**, and by tightening these bolts to the vehicle frame, the pinion-side housing **10** and the non-pinion-side housing **20** are attached to the vehicle frame with rigid construction.

The intermediate cylindrical section **30** of the steering gear unit of this example is formed using synthetic resin, so the capability for supporting the steering reaction force from the wheels is small. Therefore, in this example, by attaching the metal pinion-side housing **10** and non-pinion-side housing **20** to the vehicle frame with rigid construction, the steering reaction force from the wheels is supported by the pinion-side housing **10** and the non-pinion side housing **20**.

Moreover, the non-pinion-side housing **20** supports the intermediate cylindrical section **30** by way of a damper **34** made of an elastic material, so it is possible to reduce the radial load that is applied to this intermediate cylindrical section **30** from the bearing bushing **36**.

The rack shaft **40** is formed so that a solid shaft **41**, which is illustrated on the right side in FIG. **1** and on which the rack is formed, and a hollow shaft **42**, which is illustrated on the left side of FIG. **1** and on which a rack is not formed, are joined by friction welding. A convex engagement section **43** is formed around the junction between the solid shaft **41** and the hollow shaft **42**. This convex engagement section **43** is formed in the middle section in the axial direction between the pinion-side end section (right end section in FIG. **1**) and the non-pinion-side end section (left end section in FIG. **1**) of the rack shaft **40**, and is formed in a disk shape having a larger diameter than the outer diameter of the solid shaft **41** and hollow shaft **42**.

Therefore, when the rack shaft **40** is moved to the left side by the operator rotating the steering wheel **101** in one direction, the left side surface of the ball joint socket **51** on the right side comes in contact with the contact surface **14** on the right end of the pinion-side housing **10**. In this way, the contact surface **14** of the pinion-side housing **10** forms a movement end to the movement of the rack shaft **40** toward the non-pinion side, and restricts movement of the rack shaft **40** toward the non-pinion side (left side in FIG. **1**) beyond that point.

On the other hand, when the rack shaft **40** is moved to the right side by the operator rotating the steering wheel **101** in the other direction, the right side surface of the convex engagement section **43** provided on the rack shaft **40** comes in contact with the contact surface **15** on the left end of the pinion-side housing **10**. In this way, the contact surface **15** of the pinion-side housing **10** forms a movement end to the movement of the rack shaft **40** toward the pinion side, and restricts movement of the rack shaft **40** toward the pinion side (right side in FIG. **1**) beyond that point.

In this way, in this example, both ends of the pinion-side housing **10** in the width direction of the vehicle are used to support the thrust load that act when restricting the movement in the left and right direction of the rack **40**. Therefore, the portion of the housing section of the steering gear unit **103** for which large strength is required can be limited to the pinion-side housing **10** that has a short length in the width direction of the vehicle. Consequently, together with being able to reduce the weight of the overall housing, it is possible to reduce the manufacturing cost by simplifying the casting process and other processing.

Moreover, not only does the intermediate cylindrical section not receive the thrust load when the ball joint socket **51** on the right side or the convex engagement section **43** comes in contact with the both the left or right end of the pinion-side housing **10**, it also hardly receives the steering reaction force in the radial direction from the wheels. Therefore, there is little necessity for maintaining high strength, and it should be possible to maintain the waterproof and dustproof function of the rack shaft **40**. In addition, it is possible to form the intermediate cylindrical section **30** by injection molding of synthetic resin, and thus this intermediate cylindrical section **30** can have a thin thickness and be lightweight. Consequently, together with being able to keep the material costs low, there is no need for secondary processing, so it is also possible to reduce the processing cost.

#### Example 2

FIG. 2 is a front view with a partial cross-sectional view illustrating the main parts of a steering gear unit of a second example of an embodiment of the present invention. In the explanation below, the explanation will center on the construction that differs from that of the first example, and any redundant explanation will be omitted or simplified. This example is a variation of the first example of an embodiment, and is an example in which the material of the intermediate cylindrical section **30** is a more flexible material.

In the steering gear unit **103b** of this example, the hollow cylindrical shaped intermediate cylindrical section **30** is formed by injection molding or blow molding of rubber. The right end of this intermediate cylindrical section **30** is fastened to the pinion-side housing **10**. More specifically, the right end of the inner circumferential surface of this intermediate cylindrical section **30** fits around the outside of a cylindrical section **16** that is formed on the left end of the pinion-side housing **10**, and the right end of the intermediate cylindrical section **30** is fastened to the pinion-side housing **10** by tightening a band or wire around that right end. Alternatively, it is possible to fasten the right end of the intermediate cylindrical section **30** to the pinion-side housing **10** with adhesion by applying adhesive that functions as sealant around the outer circumferential surface of the cylindrical section **16** that is formed on the left end of the pinion-side housing **10**, and then fitting the right end of the inner circumferential surface of the intermediate cylindrical section **30** around that outer circumferential surface of the cylindrical section **16**.

On the other hand, the left end of the intermediate cylindrical section **30** is fastened to a bushing holder **37**. This bushing holder **37** has outward-facing flange sections on both end sections, and is fastened to the inner circumferential surface of the non-pinion-side housing **20** by way of a damper **34** made of an elastic material. The left end of the inner circumferential surface **35** of the intermediate cylindrical section **30** fits around the outside of the flange section on the right end side of the bushing holder **37**, and by further tightening it with a band, the left end of this intermediate cylindrical section **30** is fastened to the bushing holder **37** in a state wherein an airtight seal is maintained in the connecting section between the intermediate cylindrical section **30** and the bushing holder **37**.

In this example, the intermediate cylindrical section **30** can be such that all or part of the length has a bellows shape that can expand or contract. By forming a bellows shape, manufacturing error of each of the members is absorbed by expansion or contraction of the bellows portion, so the work of attaching the pinion-side housing **10** and non-pinion-side

housing **20** to the vehicle frame is simplified. Moreover, because the bellows portion expands or contracts, there is no need for the installation holes **131**, **211** to be long holes in the axial direction of the rack shaft **40**, and these installation holes **131**, **211** can be simple round holes. Furthermore, even in models where the length of the rack shaft **40** is different, by flexibly expanding or contracting overall length of the intermediate cylindrical section **30**, it is possible to use intermediate cylindrical section **30** in common.

A rack shaft **40** is located on the inside of the inner circumferential surface **35** of the intermediate cylindrical section **30** so as to be capable of sliding movement in the left-right direction in FIG. 3. Moreover, the bearing bushing **36** is fitted inside the bushing holder **37** to which the left end of the intermediate cylindrical section **30** is fastened, and this bearing bushing **36** supports the left end of the rack shaft **40** so as to be capable of sliding movement.

In this example as well, the ball joint sockets **51**, **52** are covered by bellows shaped ball joint boots **53**, **54** in order to be water proof and dust proof. These ball joint boots **53**, **54** can be integrally formed with the bellows shaped intermediate cylindrical section **30**.

The intermediate cylindrical section **30** of this example also cannot support the steering reaction force from the wheels. Therefore, by attaching the metal pinion-side housing **10** and non-pinion-side housing **20** to the vehicle frame with rigid construction, the steering reaction force from the wheels is supported by the pinion-side housing **10** and non-pinion-side housing **20**.

In this example, construction is such that the intermediate cylindrical section **30** is formed by injection molding of rubber that has flexibility, so the intermediate cylindrical section **30** has a thin thickness and is lightweight. Therefore, it is possible to keep material costs low, and because there is no need for secondary processing, it is possible to reduce processing costs. In the present invention, instead of a flexible material such as synthetic resin or rubber, it is also possible to manufacture the intermediate cylindrical section **30** using a light metal such as an aluminum alloy whose thickness is made thin. The other construction and function of this second example of an embodiment are the same as in the first example.

#### Variations of Example 1 And Example 2

FIG. 3 to FIG. 8 illustrate variations of the convex engagement section for restricting the movement of the rack shaft. FIG. 3 is an example in which a solid shaft is welded to a hollow shaft having a larger diameter than the solid shaft, and a separate convex engagement section is fastened to the solid shaft. More specifically, the left end of a solid shaft **41** is fitted inside the right end of the inner circumferential surface **421** of a large diameter hollow shaft **42**, and right end surface **422** of the hollow shaft **42** is welded and fastened to the outer circumferential surface **411** of the solid shaft **41**. Next, the inner circumferential surface of a ring-shaped convex engagement section **43**, which is a separate part, is fitted around the outer circumferential surface **411** of the solid shaft **41**, after which, the convex engagement section **43** is crimped and fastened to the outer circumferential surface **411** of the solid shaft **41**. Moreover, a damper **433** made of an elastic material is attached to a concave section **432** on the right end surface of the convex engagement section **43**.

With construction as described above, the rack shaft **40** moves to the right side, and the convex engagement section **43** comes in contact via the damper **433** made of elastic material with the contact surface **15** on the left end of the pinion-side

housing 10 such as illustrated in FIG. 1 and FIG. 2, so it is possible to lessen impact loads during contact. In addition, it is not necessary to increase the strength of parts such as the rack shaft 40 and pinion shaft 107, and thus it is possible to make the parts more compact and lightweight.

FIG. 4 is an example of welding a solid shaft to the right end side of a hollow shaft, the diameter of which has been expanded, and fastening the separate convex engagement section to the solid shaft. More specifically, the left side of a hollow shaft 42 is taken to be a small-diameter hollow section 423, and a large-diameter hollow section 424 is only formed on the right end side. A solid shaft 41 is fitted inside the inner circumferential surface 4241 of the large-diameter hollow section 424, and the right end surface 4242 of the large-diameter hollow section 424 is welded and fastened to the outer circumferential surface 411 of the solid shaft 41. Next, the inner circumferential surface 431 of the ring-shaped convex engagement section 43, which is a separate part, is fitted around the outer circumferential surface 411 of the solid shaft 41, after which the convex engagement section 43 is crimped and fastened to the outer circumferential surface 411 of the solid shaft 41.

With the construction described above, the hollow shaft 42 can be such that it supports only the steering reaction force from the wheels and not the thrust load when the ball joint socket 51 on the right side as illustrated in FIG. 1 and FIG. 2 or the convex engagement section 43 come in contact with both the left and right ends of the pinion-side housing 10. Therefore, it is possible to use a thin-walled, lightweight hollow material, and together with being able to keep material costs low it is possible to reduce the weight.

FIG. 5 is an example where a solid shaft is welded to a hollow shaft, and the convex engagement section is integrally formed with the hollow shaft 42. More particularly, a flange shaped convex engagement section 43 is integrally formed on the right end of a hollow shaft 42. Then, together with fitting a small-diameter solid section 414 that is on the left end of the solid shaft inside the right end of the inner circumferential surface 421 of the hollow shaft 42, the right end surface 434 of the convex engagement section 43 is welded and fastened to the outer circumferential surface 411 of the solid shaft 41. With this kind of construction, the convex engagement section 43 is integrally formed with the hollow shaft 42, so it is possible to reduce the number of parts, and thus it is possible to reduce the manufacturing cost.

FIG. 6 is an example of inserting and fastening a separate ring shaped convex engagement section in a ring shaped groove that is formed around the outer circumferential surface of the solid shaft. More specifically, together with forming a ring shaped groove 412 that is recessed inward in the radial direction around the outer circumferential surface 411 of the solid shaft 41, this snap ring shaped convex engagement section 43 is fastened to the solid shaft 41 by fitting the convex engagement section 43 around this ring shaped groove 412.

FIG. 7 is an example where a solid shaft is fitted around a hollow shaft and welded, and a convex engagement section is integrally formed with the solid shaft. More specifically, together with integrally forming an outward-facing flange shaped convex engagement section 43 on the left end of a solid shaft 41, and a small-diameter hollow section 425 is formed on the right end of the hollow shaft 42. Then, this small-diameter hollow section 425 of the hollow shaft 42 is fitted on the inside of the inner circumferential surface 413 on the left end of the solid shaft 41. After that, the left end surface 435 of the convex engagement section 43 and the outer circumferential surface 426 of the solid shaft 42 are welded and fastened together.

With this kind of construction, the rack shaft 40 moves toward the right side in FIG. 7, and when the convex engagement section 43 comes in contact with the contact surface 15 on the left side of the pinion-side housing 10 as illustrated in FIG. 1 and FIG. 2, the welded section 44 supports the convex engagement section 43 from the rear, and prevents the convex engagement section from tilting. Therefore, it is possible to increase the rigidity of the convex engagement section 43. Moreover, the convex engagement section 43 is integrally formed with the solid shaft 41, so it is possible to reduce the number of parts, and thus it is possible to reduce the manufacturing cost.

FIG. 8 is an example where, together with the end surface of a hollow shaft in contact with the end surface of the solid shaft and welding, a convex engagement section is integrally formed with the end section of the solid shaft. More specifically, an outward-facing flange shaped convex engagement section 43 is integrally formed on the left end of a solid shaft 41. Then the right end surface 422 of a hollow shaft 42 is brought into contact with the left end surface 435 of the convex engagement section 43. After that, the left end surface of the convex engagement section 43 and the outer circumferential surface 426 of the hollow shaft 42 are welded and fastened together.

With the construction described above, the rack shaft 40 moves to the right side in FIG. 8, and together with the convex engagement section 43 coming in contact with the contact surface 15 on the left end of the pinion-side housing 10 such as illustrated in FIG. 1 and FIG. 2, the weld section 44 supports the convex engagement section 43 from the rear and prevent the convex engagement section from tilting. Therefore, it is possible to increase the rigidity of the convex engagement section 43. Moreover, the convex engagement section 43 is integrally formed with the solid shaft 41, so it is possible to reduce the number of parts, and thus it is possible to reduce the manufacturing cost.

In the first and second examples of an embodiment, examples of applying the present invention to a column assist type rack and pinion type power steering apparatus were explained, however, the present invention can also be applied to a pinion assist type of rack and pinion type power steering apparatus, or a manual rack and pinion steering apparatus.

#### Example 3

FIG. 9 is a top view that illustrates the main part of a steering gear unit 103c of a steering apparatus of a third example of an embodiment of the present invention. In the following explanation, explanations that are redundant with the examples of the embodiment above are omitted or simplified, and the same reference numbers are given to identical parts. The steering gear unit 103c of this example is attached to the vehicle frame (not illustrated in the figure) such as the front sub frame. The front side that is orthogonal to the paper surface in FIG. 9 is the upward side of the vehicle, the back side that is orthogonal to the paper surface in FIG. 9 is the downward side of the vehicle, the left-right direction in FIG. 9 is the left-right direction of the vehicle, the upward direction in FIG. 9 corresponds to forward direction of the vehicle and the downward direction in FIG. 9 corresponds to the backward direction of the vehicle.

The steering gear unit 103c comprises a pinion-side housing 10 on the right side in FIG. 9, a non-pinion-side housing 20 on the left side in FIG. 9, and an intermediate cylindrical section 30 that connects the pinion-side housing 10 and the non-pinion-side housing 20.

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The pinion-side housing **10** and the non-pinion-side housing **20** are formed by casting metal such as an aluminum alloy. On the other hand, a non-metallic material having flexibility such as synthetic resin or rubber is used for the hollow cylindrical shaped intermediate cylindrical section **30**, and this intermediate cylindrical section **30** is formed by injection molding or blow molding. Synthetic resin or rubber is lightweight when compared with a metal material, and together with having large elasticity, is flexible and can expand or contract.

The right end of this kind of intermediate cylindrical section **30** is fastened to the left end of the pinion-side housing **10**. More specifically, together with inserting a cylindrical section (not illustrated in the figure) that is formed on the left end of the pinion-side housing **10** into the right end of the inner circumferential surface **35** of the intermediate cylindrical section **30**, the right end of the intermediate cylindrical section **30** and the left end of the pinion-side housing **10** are fastened by a band **55**.

On the other hand, the left end of the intermediate cylindrical section **30** is fastened to the right end of the non-pinion-side housing **20**. More specifically, together with inserting a cylindrical section (not illustrated in the figure) that is formed on the right end of the non-pinion-side housing **20** into the left end of the inner circumferential surface **35** of the intermediate cylindrical section **30**, the left end of the intermediate cylindrical section **30** and the right end of the non-pinion-side housing **20** are fastened by a band **55**. As a result, both end of the intermediate cylindrical section **30** are fastened using bands **55**, so it is possible to main an airtight seal in the connecting sections. Alternatively, wire could be used for fastening instead of bands **55**.

In this example, in a state of being adjacent to a column shaped boss **12**, a column shaped boss **56** for inserting a rack guide that protrudes toward the rear of the vehicle (toward the downward side of FIG. **9**) is integrally formed on the pinion-side housing **10**. A rack guide (not illustrated in the figure) is inserted into this column shaped boss **56** for inserting a rack guide. This rack guide, using rollers or the like, guides the rear surface (surface on the opposite side from the rack teeth side) of the rack shaft **40**, and by preventing deformation of the rack shaft **40** due to a reaction force that occurs when engaging with the pinion, allows for the rack shaft **40** to slide smoothly.

In this example as well, the intermediate cylindrical section **30** is formed using synthetic resin or rubber having flexibility, and because the intermediate cylindrical section **30** has elasticity and flexibility, its ability to support the steering reaction force from the wheels is small or it cannot support the steering reaction force at all. Therefore, in this example, by attaching the metal pinion-side housing **10** and the non-pinion-side housing **20** to the vehicle frame with rigid construction, the pinion-side housing **10** and the non-pinion-side housing **20** support the steering reaction force from the wheels.

Moreover, the intermediate cylindrical section **30** of this example is formed using a non-metallic material having flexibility such as synthetic resin or rubber, so when compared with making this intermediate cylindrical section **30** using a metallic material, it is lightweight, and together with having large elasticity, is flexible, and can expand and contract. In addition, when compared with using a metallic material, together with being able to reduce the weight, it is possible to keep material costs low. Furthermore, there is no need for secondary processing, so it is also possible to reduce processing costs.

In the case of this example as well, the pinion shaft **107** is located on or near the connecting line between the two installation holes **131** that are formed in the pinion-side housing **10**.

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Therefore, it is possible to effectively receive the reaction force from the rack and pinion during steering. The other construction and functions of this third example of the embodiment are the same as in the first and second examples of the embodiment.

## Example 4

FIG. **10** is a top view illustrating the main parts of a steering gear unit **103d** of a steering apparatus of a fourth example of an embodiment of the present invention. This example is a variation of the third example of the embodiment, so together with omitting or simplifying any explanations of portions that are redundant with the third example, the same reference numbers are given to identical parts. This example is an example where bellows are formed on both ends of the intermediate cylindrical section **30**.

In other words, in this example, a non metal material having flexibility such as synthetic resin or rubber is used, and expanding and contracting bellows **57** are formed on the right end and the left end of the intermediate cylindrical section **30** that is formed by injection molding or blow molding.

In the case of this example, bellows **57** that can expand and contract are formed on both ends of the intermediate cylindrical section **30**, so manufacturing error or assembly error of the members is absorbed by the expansion or contraction of the bellows **57**, and thus the work of attaching the pinion-side housing **10** and the non-pinion-side housing **20** to the vehicle frame becomes easier. The bellows **57** expand or contract, so the installation holes **131**, **211** do not need to be long holes that are long in the axial direction of the rack shaft **40**, and thus these installation holes **131**, **211** can be simple round holes.

## Example 5

FIG. **11** is a top view that illustrates the main parts of a steering gear unit **103e** of a steering apparatus of a fifth example of an embodiment of the present invention. This example is a variation of the third example of the embodiment, so together with omitting or simplifying any explanations of portions that are redundant with the third example, the same reference numbers are given to identical parts. This example is an example where a bellows is formed along the entire length of the intermediate cylindrical section **30**.

In other words, in this example, a non-metallic material having flexibility such as synthetic resin or rubber is used, and a bellows **58** that can expand and contract is formed along the entire length of a the intermediate cylindrical section **30** that was formed by injection molding or blow molding.

In the case of this example, a bellows **58** that can expand or contract is formed along the entire length of the rack shaft **40**, so even in the case of models having rack shafts **40** of different lengths, by flexibly expanding or contracting the entire length of the intermediate cylindrical section **30**, the intermediate cylindrical section **30** can be used in common.

## Example 6

FIG. **12** is a top view with a partial cross-sectional view that illustrates the main parts of a steering gear unit **103f** of a steering apparatus of a sixth example of an embodiment of the present invention, and FIG. **13** is a vertical cross-sectional view illustrating the engagement section between the pinion and the rack in FIG. **12**. This example is a variation of the third example of the embodiment, so together with omitting or simplifying any explanations of portions that are redundant

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with the third example, the same reference numbers are given to identical parts. This example is an example of applying the present invention to a pinion assist type of rack and pinion power steering apparatus.

In the steering gear unit 103f of this example, the upward direction in FIG. 12 is the upward side of the vehicle, the downward direction is the downward side of the vehicle, the left-right direction in FIG. 12 is the left-right direction of the vehicle, and the direction orthogonal to the paper surface in FIG. 12 is the forward-backward direction of the vehicle.

As illustrated in FIG. 13, the bottom end section of the pinion shaft 02 is supported by a ball bearing 031 so as to be able to rotate. Moreover, a locking nut 032 is screwed onto male threads 021 that are formed around the outer circumferential surface of the bottom end section of the pinion shaft 02. This locking nut 032 supports and fastens the inner ring of the ball bearing 031 to a specified position on the bottom end section of the pinion shaft 02.

The outer ring of the ball bearing 031 is pressure fitted into a bearing hole 042 that is formed in a lower gear box 041 that is provided on the lower half section of the pinion-side housing 10. The outer ring of the ball bearing 031 is pressed upward, and supported by and fastened to the lower gear box 041 by an end cover 033 that is screwed into female threads 043 that are formed around the inner circumferential surface of the end section on the opening side of the bearing hole 042.

Moreover, the metal core 052 of a worm wheel 051 that engages with the worm 053 of a worm reducer 05 is pressure fitted into the top end section of the pinion shaft 02. This worm 053 is connected to the output shaft of an electric motor 054 (see FIG. 12) for steering assistance. The lower portion of the portion of the pinion shaft 02 into which the worm wheel 051 is pressed is supported by a ball bearing 034 so as to be able to rotate with respect to the lower gear box 041 and so that force in the radial direction is supported.

On the other hand, in an upper gear box 044 that is fastened to the top end surface of the lower gear box 041, an input shaft 06 that is connected to the steering wheel 101 by way of an intermediate shaft 106 such as illustrated in FIG. 14 is supported by a ball bearing 061 so as to be able to rotate. A torsion bar 063 that is connected at the top end to this input shaft 06 by a pin 062 is supported around the bottom end by a bushing 064, and the portion further below this bushing 064 is connected by a press fit to the top end section of the pinion shaft 02.

A torque sensor 07 for detecting torque that acts on the torsion bar 063 that is connected as described above comprises a sensor shaft section 071, a pair of detection coils 073, 074, and a cylindrical member 075. The sensor shaft section 071 is formed on the bottom end section of the input shaft 06, and a plurality of convex ridges that extend in the axial direction are formed at uniform intervals in the circumferential direction. Moreover, the detection coils 073, 074 are located on the inside of a yoke that is pressed into the upper gear box 044. Furthermore, the cylindrical member 075 is located between the sensor shaft section 071 and the detection coils 073, 074, and is fastened to the top end of the pinion shaft 02. A plurality of rectangular windows that are evenly spaced in the circumferential direction are formed at positions that face the detection coils 073, 074.

By operating the steering wheel 101, the input shaft 06 rotates, and that rotation force is transmitted to the pinion shaft 02 by way of the torsion bar 063. When this happens, twisting occurs in the torsion bar 063 that connects the input shaft 06 and the pinion shaft 02 due to resistance from the steered wheels, and relative rotation occurs between the convex ridges that are formed on the surface of the sensor shaft

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section 071 and the windows in the cylindrical member 075. As a result, a magnetic flux that occurs in the sensor shaft section 071 increases or decreases.

This increase or decrease in magnetic flux that occurs in the sensor shaft section 071 is detected as change in the inductance in the detection coils 073, 074, and from this the torque acting on the torsion bar 063 is detected. Based on this, the electric motor 054 is driven, and the worm 053 is caused to rotate with the required auxiliary steering force. The rotation of the worm 053 is transmitted to the worm wheel 051, the pinion shaft 02 and the rack shaft 40, and changes the steering direction by way of the tie rods 104 that are connected to the rack shaft 40.

A rack guide 08 presses a roller 083 against the back surface of the rack shaft 40 by way of an adjustment cover 084. This roller 083 is supported by a shaft 081 and a needle bearing 082 that is located around the shaft 081 so as to be able to rotate. The adjustment cover 084 presses the roller 083 against the back surface of the rack shaft 40 by way of a plate spring. As a result, it is possible to eliminate backlash in the engagement section between the pinion 022 and the rack shaft 40, and thus the rack shaft 40 can move smoothly.

As illustrated in FIG. 12, boss sections 13, 21 for attachment to the vehicle body are formed on the pinion-side housing 10 and the non-pinion-side housing 20 and protrude in the forward-backward direction of the vehicle (up-down direction in FIG. 12). One circular installation hole 131, 211 is formed in the up-down direction of the vehicle (orthogonal direction to the paper surface in FIG. 13) in each of the boss sections 13, 21 for attachment to the vehicle.

Bolts (not illustrated in the figure) are inserted in the installation holes 131, 211, and by tightly attaching the bolts to the vehicle frame, the pinion-side housing 10 and the non-pinion-side housing 20 are attached to the vehicle body with rigid construction.

The intermediate cylindrical section 30 of this example is also formed using synthetic resin or rubber having flexibility, and because the intermediate cylindrical section 30 has elasticity and flexibility, its ability to support the steering reaction force from the wheels is small or impossible. Therefore, in this example, by attaching the metal pinion-side housing 10 and the non-pinion-side housing 20 to the vehicle frame with rigid construction, the pinion-side housing 10 and non-pinion-side housing 20 support the steering reaction force from the wheels.

Moreover, non-metallic material having flexibility such as synthetic resin or rubber is used for the intermediate cylindrical section 30 of this example, so when compared with construction using a metallic material, the intermediate cylindrical section 30 is lightweight, and together with having large elasticity, has flexibility and is able to expand and contract. In addition, when compared with the case of using a metallic material, together with being able to make the intermediate cylindrical section 30 more lightweight, it is possible to keep material costs low. Furthermore, there is no need for secondary processing, so processing costs can also be reduced.

In the third to sixth examples of the embodiment, cases of applying the present invention to a column assist type of rack and pinion type power steering apparatus, and a pinion assist type of rack and pinion power steering apparatus were explained, however, the present invention can also be applied to a manual type of rack and pinion steering apparatus.

The present invention is not limited to the construction of the examples of the embodiment described above, and various modifications are possible, and embodiments that are

obtained by suitably combining the technological means disclosed are also included within the technical scope of the present invention.

## EXPLANATION OF REFERENCE NUMBERS

101 Steering wheel  
 102 Motor  
 103, 103a to 103f Steering gear unit  
 104 Tie rod  
 105 Column  
 106 Intermediate shaft  
 107 Pinion shaft  
 108 Cylinder section  
 109 Rack shaft  
 110 Gear housing  
 111 Main housing section  
 112 Sub housing section  
 10 Pinion-side housing  
 11 Female threads  
 12 Column shaped boss  
 13 Boss section for attachment to the vehicle  
 131 Installation hole  
 14 Contact surface  
 15 Contact surface  
 16 Cylindrical section  
 20 Non-pinion-side housing  
 21 Boss section for attachment to the vehicle  
 211 Installation hole  
 30 Intermediate cylindrical section  
 31 Male threads  
 32 O-ring  
 33 Flange section  
 34 Damper  
 35 Inner circumferential surface  
 36 Bearing bushing  
 37 Bushing holder  
 40 Rack shaft  
 41 Solid shaft  
 411 Outer circumferential surface  
 412 Ring shaped groove  
 413 Inner circumferential surface  
 414 Small-diameter solid section  
 42 Hollow shaft  
 421 Inner circumferential surface  
 422 Right end surface  
 423 Small-diameter hollow section  
 424 Large-diameter hollow section  
 4241 Inner circumferential surface  
 4242 Right end surface  
 425 Small-diameter hollow section  
 426 Outer circumferential surface  
 43 Convex engagement section  
 431 Inner circumferential surface  
 432 Convex section  
 433 Damper  
 434 Right end surface  
 435 Left end surface  
 44 Weld section  
 51, 52 Ball joint socket  
 53, 54 Ball joint boot  
 55 Band  
 56 Column shaped boss  
 57 Bellows  
 58 Bellows  
 59 Cylindrical section  
 60 Cylindrical section

02 Pinion shaft  
 021 Male threads  
 022 Pinion  
 031 Ball bearing  
 5 032 Locking nut  
 033 End cover  
 034 Ball bearing  
 041 Lower gear box  
 042 Bearing hole  
 10 043 Female threads  
 044 Upper gear box  
 05 Worm reducer  
 051 Worm wheel  
 052 Metal core  
 15 053 Worm  
 054 Electric motor  
 06 Input shaft  
 061 Ball bearing  
 062 Pin  
 20 063 Torsion bar  
 064 Bushing  
 07 Torque sensor  
 071 Sensor shaft section  
 072 Yoke  
 25 073, 074 Detection coil  
 08 Rack guide  
 081 Shaft  
 082 Needle Bearing  
 083 Roller  
 30 084 Adjustment cover  
 What is claimed is:  
 1. A rack and pinion steering gear unit, the unit comprising:  
 a rack shaft that reciprocates according to rotation of a  
 pinion shaft;  
 35 ball joint sockets that are formed on both end of the rack  
 shaft and have a larger diameter than the rack shaft;  
 a pinion-side housing made of metal that supports a pinion-  
 side end section of the rack shaft where the pinion shaft  
 is located so that sliding movement of the rack shaft is  
 possible, and that can be fastened to a vehicle frame;  
 40 a non-pinion-side housing made of metal that supports the  
 non-pinion-side end section of the rack shaft so that  
 sliding movement of the rack shaft is possible, and that  
 can be fastened to the vehicle frame; and  
 45 a hollow cylindrical shaped intermediate cylindrical section  
 that is connected to the pinion-side housing on one  
 end, and is connected to the non-pinion-side housing on  
 the other end, and covers the middle section of the rack  
 shaft;  
 50 a convex engagement section that is formed in the middle  
 section in the axial direction of the rack shaft between  
 the pinion-side end section and the non-pinion-side end  
 section that is on the opposite side from the pinion-side  
 end section, and that has a larger diameter than the rack  
 shaft so as to move together with the rack shaft, and  
 55 as the rack shaft displaces, one of the ball joint sockets that  
 is attached to the pinion-side end section coming in  
 contact with one end of the pinion-side housing, and  
 restricting movement of the rack shaft toward the non-  
 pinion side, and the convex engagement section coming  
 60 in contact with the other end of the pinion-side housing,  
 and restricting movement of the rack shaft toward the  
 pinion side.  
 2. The rack and pinion steering gear unit according to claim  
 65 1, wherein the non-pinion-side housing supports the non-  
 pinion-side end section of the rack shaft by way of an elastic  
 member so that sliding movement of the rack shaft is possible.

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3. The rack and pinion steering gear unit according to claim 1, wherein the rack shaft is formed by connecting a solid shaft on which a rack is formed and a hollow shaft on which the rack is not formed, and the convex engagement section is formed around the connecting section between the solid shaft and the hollow shaft.

4. The rack and pinion steering unit according to claim 1, wherein a damper made of an elastic material is attached to the contact surface of the convex engagement section that comes in contact with the other end of the pinion-side housing.

5. The rack and pinion steering unit according to claim 1, wherein the intermediate cylindrical section can expand and contract in the axial direction of the rack shaft.

6. The rack and pinion steering unit according to claim 1, wherein the material of the intermediate cylindrical section is synthetic resin.

7. The rack and pinion steering unit according to claim 1, wherein the material of the intermediate cylindrical section is rubber.

8. A rack and pinion steering gear unit, the unit comprising:  
a rack shaft that reciprocates according to rotation of a pinion shaft;  
ball joint sockets that are formed on both end of the rack shaft and have a larger diameter than the rack shaft;  
a pinion-side housing made of metal that supports a pinion-side end section of the rack shaft where the pinion shaft

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is located so that sliding movement of the rack shaft is possible, and that can be fastened to a vehicle frame;

a non-pinion-side housing made of metal that supports the non-pinion-side end section of the rack shaft so that sliding movement of the rack shaft is possible, and that can be fastened to the vehicle frame; and

a hollow cylindrical shaped intermediate cylindrical section that is connected to the pinion-side housing on one end, and is connected to the non-pinion-side housing on the other end, and covers the middle section of the rack shaft;

a convex engagement section that is formed in the middle section in the axial direction of the rack shaft between the pinion-side end section and the non-pinion-side end section that is on the opposite side from the pinion-side end section, and that has a larger diameter than the rack shaft so as to move together with the rack shaft,

the rack shaft supported at two positions of the pinion-side housing and the non-pinion-side housing;

as the rack shaft displaces, one of the ball joint sockets that is attached to the pinion-side end section coming in contact with one end of the pinion-side housing, and restricting movement of the rack shaft toward the non-pinion side, and the convex engagement section coming in contact with the other end of the pinion-side housing, and restricting movement of the rack shaft toward the pinion side.

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